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HUGH G. CALKINS
REGIONAL CONSERVATOR

MAN AND GULLIES

BY

HUGH G. CALKINS

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FOREWORD

THERE ARE AT LEAST TWO SCHOOLS OF THOUGHT WITH REGARD TO THE PRESENT CYCLE OF EROSION IN THE WEST AND SOUTHWEST. ONE SCHOOL OF THOUGHT LEANS TOWARD THE BELIEF THAT TODAY'S EROSION IS LARGELY A RESULT OF CLIMATIC CHANGE, A CHANGE TO A MORE ARID CLIMATE. THE OTHER SCHOOL OF THOUGHT BELIEVES THAT THE PRESENT EROSION CYCLE IS LARGELY DUE TO MAN'S DISTURBANCE OF PLANT COVER THROUGH OVERGRAZING, BUILDING OF ROADS AND TRAILS, AND OTHER ACTIVITIES.

NEITHER SCHOOL NEGLECTS THE VIEWPOINT OF THE OTHER IN DRAWING ITS OWN CONCLUSIONS. BUT EACH LEANS WELL AWAY FROM THE OTHER, ONE TOWARDS MAN AS A FACTOR, THE OTHER TOWARDS CLIMATE. THE FOLLOWING ARTICLE IS ONE OF THE MOST COMPLETE PRESENTATIONS OF ONE POINT OF VIEW.

MAN AND GULLIES

BY

HUGH G. CALKINS[1]

THERE HAVE DEVELOPED A NUMBER OF CONCEPTS REGARDING THE INFLUENCE OF MAN'S USE OF THE EARTH UPON HIS ENVIRONMENT. A VIEW THAT IS FAIRLY GENERAL TODAY, BUT BY NO MEANS NEW, IS THAT IN OUR OCCUPATION AND USE OF THE LAND WE TRANSFORM IT. BUT IT IS ONLY RELATIVELY RECENTLY THAT WE HAVE ASSUMED RESPONSIBILITY FOR OUR ACTION. WE HAVE LONG SEEN OURSELVES AS VICTIMS OF OUR ENVIRONMENT, BUT HAVE NOT LONG SEEN OURSELVES AS AN ACTIVE PART OF THAT ENVIRONMENT. THE EFFECT OF MAN UPON THE EARTH'S SURFACE AND ITS PROCESSES IS WELL EXPRESSED BY DOCTOR SAUER[2] WHEN HE SAYS, "THE LATEST AGENT TO MODIFY THE EARTH'S SURFACE IS MAN. MAN MUST BE REGARDED DIRECTLY AS A GEOMORPHOLOGIC AGENT, FOR HE HAS INCREASINGLY ALTERED THE CONDITIONS OF DENUDATION AND AGGRADATION OF THE EARTH'S SURFACE; AND MANY AN ERROR HAS CREPT INTO PHYSICAL GEOGRAPHY BECAUSE IT WAS NOT SUFFICIENTLY RECOGNIZED THAT THE MAJOR PROCESSES OF PHYSICAL SCULPTURING OF THE EARTH CANNOT BE SAFELY INFERRED FROM THE PROCESSES THAT ONE SEES AT WORK TODAY UNDER HUMAN OCCUPATION. INDEED, A CLASS OF FACTS WHICH BRUNHES LABELED AS 'FACTS OF DESTRUCTIVE OCCUPATION' SUCH AS SOIL EROSION, ARE MOST LITERALLY EXPRESSIONS OF HUMAN GEOMORPHOSIS."

AS APPLIED TO EROSION ON CULTIVATED LANDS, THIS POINT OF VIEW IS ALMOST UNIVERSAL. BUT, AS EVIDENCED BY DOCTOR BRYAN'S RECENT ARTICLE EROSION IN THE SOUTHWEST[3], SOME FIND IT INAPPLICABLE TO THE RANGES OF THE SEMI-ARID SOUTHWEST, WHERE THEY WOULD HOLD ENVIRONMENTAL FACTORS OTHER THAN MAN CHIEFLY ACCOUNTABLE.

DOCTOR BRYAN MINIMIZES MAN'S RESPONSIBILITY WHEN HE EXPRESSES THE BELIEF THAT THE LAND PROBLEMS OF THE SOUTHWEST "MAY BE OVERCOME BY A GENEROUS NATURE, RETURNING GOOD FOR EVIL."

IF THE CULTURE OF MAN SOMETIMES HAS ADVERSE EFFECTS UPON HIS ENVIRONMENT AND SECONDARILY UPON HIMSELF, IT WOULD SEEM THAT THE RESPONSIBILITY FOR APPRAISING AND REMEDYING THOSE EFFECTS IS THE RESPONSIBILITY OF SOCIETY RATHER THAN OF THE INDIVIDUAL -- THAT IF INDIVIDUALS ARE VICTIMS OF DAMAGE WHOSE CAUSES THEY HAVE NO MEANS OF CONTROLLING, THE PROBLEM IS A GROUP CONCERN.

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1 REGIONAL CONSERVATOR, SOIL CONSERVATION SERVICE, SOUTHWEST REGION

2 CARL SAUER, CULTURAL GEOGRAPHY; ENCYCLOPEDIA OF THE SOCIAL SCIENCES; VOL. 3, P. 622

3 NEW MEXICO QUARTERLY, NOVEMBER 1940

THE COMMUNITY OR THE NATION CANNOT AFFORD TO LOOK UPON ITS IRREPLACEABLE RESOURCES AS AN INDIVIDUAL MIGHT LOOK UPON THE DESTRUCTION OF AN ACRE OF LAND OR EVEN OF HIS ENTIRE FARM. THE INDIVIDUAL CAN GIVE A PURELY DOLLAR VALUATION OF HIS SOILS, HIS ACRES OF FARMLAND. IF HE IS SOLVENT HE CAN BUY ANOTHER FARM OR RANCH WHEN HE HAS DAMAGED OR DESTROYED THE ORIGINAL ONE. NATIONALLY AND REGIONALLY, HOWEVER, THE OPPORTUNITIES FOR MOVING TO NEW FARMS AND NEW JOBS ARE DECIDEDLY RESTRICTED. SO, FROM THE SOCIAL POINT OF VIEW, AN ECONOMIC JUSTIFICATION OF THE CONSERVATION OF NATURAL RESOURCES BASED ONLY ON THE CURRENT MARKET VALUE OF LAND IS NOT ENTIRELY SATISFACTORY. A CONSERVATION PROGRAM THAT BEST APPORTIONS AND USES THE LIMITED FUNDS AT ITS DISPOSAL MUST WEIGH ALL FACTORS: PROPERTY DAMAGE, COST OF SOIL LOSSES, THE IMMOBILITY OF ESTABLISHED CITIES AND COMMUNITIES, AND THE HUMAN AND ECONOMIC COST INVOLVED IN THE MIGRATION OF PEOPLE FROM AREAS DESTROYED BY MISUSE.

IN THE PRESENT DAY IT WOULD SEEM PRETTY DISASTROUS FOR US TO VALUE IRREPLACEABLE RESOURCES IN THE SAME WAY WE VALUE RAZOR BLADES. AND YET DOCTOR BRYAN APPEARS TO DO THIS WHEN HE REPEATEDLY CALLS FOR THIS TYPE OF VALUATION AND MEASURES DESTRUCTION OF SOIL AND WATER IN TERMS OF PURELY INDIVIDUAL VALUES. HE ASKS FOR MEASUREMENT OF DAMAGE ONLY "IN THE COMMON DENOMINATOR OF THE DOLLAR," AND SUGGESTS THAT, "THE CONTROL OF EROSION.....SHOULD NOT COST MORE THAN THE VALUE OF THE STORED WATER THAT WOULD OTHERWISE BE LOST."

SUCH AN ECONOMIC VIEW SEEMS PARTICULARLY OPEN TO QUESTION BECAUSE, APPARENTLY, IT IS NOT ONLY ENTIRELY BASED ON A DOLLAR VALUATION OF RESOURCES BUT FAILS TO CONSIDER ANY PROPERTY DAMAGE SUSTAINED FROM EROSION EXCEPT THE LOSS OF IRRIGATION WATER THROUGH RESERVOIR SILTING - ONLY ONE OF THE SEVERAL MAJOR ELEMENTS OF DAMAGE.

THE RAPID RISE OF SILT IN THE CHANNEL OF THE RIO GRANDE, FOR INSTANCE, IS OF MUCH MORE IMMEDIATE AND, POSSIBLY, LASTING CONCERN TO TENS OF THOUSANDS OF PEOPLE LIVING ON FARMS AND IN THE TOWNS AND CITIES ALONG THE RIO GRANDE THAN IS THE SILTING OF ELEPHANT BUTTE DAM. WE MAY BE ABLE TO BUILD ANOTHER DAM; WE CANNOT BUILD ANOTHER RIVER. YET DOCTOR BRYAN SAYS THAT "THE INCREASED LOAD OF MUD WILL, WITHIN A FEW GENERATIONS OF MEN, FILL THE RESERVOIRS AND RENDER THEM VALUELESS FOR STORAGE. THIS IS THE GREAT 'ARROYO PROBLEM.'" UNFORTUNATELY, THAT PROBLEM IS NOT SO LIMITED IN SCOPE. IN 1880, ABOUT 100,000 ACRES WERE UNDER CULTIVATION IN THE MIDDLE RIO GRANDE VALLEY; BY 1925, CHANNEL SILTING AND WATER-LOGGING OF VALLEY LANDS HAD REDUCED THIS ACREAGE TO 40,000. THE MIDDLE RIO GRANDE CONSERVANCY DISTRICT HAS BEEN FORMED AND HAS SPENT SEVERAL MILLION DOLLARS TO DRAIN, PROTECT, AND RESTORE PART OF THE LOST FARMLAND. THE DEEP CUTTING OF THE RIO PUERCO VALLEY HAS LEFT MOST OF ITS ONCE IRRIGATED FARMS HIGH AND DRY. AT SAN MARCIAL, BELOW SOCORRO, THE RIVER BED HAS RISEN TWELVE FEET WITH SILT DEPOSITS IN FORTY-EIGHT YEARS, AND THE TOWN OF SAN MARCIAL ITSELF HAS BEEN DESTROYED BY FLOODS. THESE CONDITIONS, TOO, ARE PART OF THE "GREAT ARROYO PROBLEM."

DOCTOR BRYAN CONSIDERS THE COST OF ERDSION CONTROL, SAYING THAT "THE SPENDING OF TEN DOLLARS AN ACRE ON LAND THAT THE GOVERNMENT HAS PURCHASED AT FROM FIFTY-EIGHT CENTS TO TWO DOLLARS AND FIFTY CENTS CANNOT LONG BE JUSTIFIED...." THIS CONCERN OVER THE SPENDING OF $10 PER ACRE ON LAND WORTH FIFTY CENTS SEEMS REASONABLE ENOUGH. SUCH AN EXPENDITURE ON EACH ACRE OF WATERSHED ERODING LAND MIGHT WELL REPRESENT AN INEFFICIENT AND UNINTELLIGENT APPROACH TO THE EROSION PROBLEM AND ITS SOLUTION. AS A MATTER OF FACT, MANY ACRES NEED NO TREATMENT OF ANY KIND EXCEPT CONSERVATIVE USE. OTHER ACRES IN A CRITICAL AREA MAY BE THE SITE OF A STRUCTURE COSTING $10 OR $1,000, BUT BENEFITING OR SAFEGUARDING A GOOD MANY HUNDREDS OF ACRES OF LAND OR OTHER PROPERTY.

THE VIEW OF EROSION PRESENTED IN THIS PAPER DIFFERENTIATES BETWEEN THE NORMAL DEVELOPMENT OF SOUTHWESTERN VALLEYS BY EROSION DURING QUATERNARY AND RECENT GEOLOGIC PERIODS, AND THE PRESENT PERIDO OF ACTIVE GULLY CUTTING WHICH STARTED IN THE SOUTHWEST ABOUT 1885. BUT BRYAN CONSIDERS THE PRESENT ACTIVE ERDSION A NATURAL PART OF THE GEOLOGIC CYCLE, WITH OVERGRAZING ACTING AS NO MORE THAN A TRIGGER PULL TO SET THE INEVITABLE FORCES IN MOTION. HE BASES HIS HYPOTHESIS ON THE FACT THAT, IN MANY ALLUVIAL VALLEYS NOW ERODING, WE FIND REMNANTS OF OLD ARROYOS NOW FILLED. SINCE THESE REMNANTS OF OLD ARROYOS WERE CUT BEFORE THE INTRODUCTION OF DOMESTIC LIVESTOCK, HE ATTRIBUTES THESE OLD, BURIED CHANNELS AND THE PRESENT ARROYOS, WHICH HE CONSIDERS ENTIRELY COMPARABLE, TO CLIMATIC CHANGE. HIS THESIS, IN ESSENCE, IS THAT A SHIFT TO A DRIER CLIMATE RESULTS IN EROSION; A SHIFT TO A WETTER, HUMID CLIMATE RESULTS IN AGGRADATION.

OUR THESIS HERE IS THAT THE BURIED CHANNELS ARE NOT COMPARABLE TO THE PRESENT ARROYOS IN THAT THE FORMER ARE REMNANTS OF DISCONTINUOUS GULLIES; THAT DISCONTINUOUS GULLIES ARE A NATURAL PART OF VALLEY DEVELOPMENT IN THE SOUTHWEST; AND THAT THESE DISCONTINUOUS GULLIES ARE THE RESULT OF VACILLATIONS IN RAINFALL NOT INVOLVING CLIMATIC CHANGE.

AN APPRAISAL OF THE CONFLICTING VIEWS REQUIRES A DISCUSSION OF THE MECHANICS OF EROSION AS THEY APPLY TO SOUTHWESTERN CONDITIONS.

EROSION IN THE SOUTHWEST IS THE RESULT OF SURFACE RUN-OFF MODIFIED BY ENVIRONMENTAL FACTORS. IN THE SOUTHWEST THERE IS A WIDE VARIATION IN AMOUNT OF ANNUAL PRECIPITATION, IN SEASONAL OCCURRENCE, AND IN INTENSITY OF INDIVIDUAL RAINSTORMS. IN GENERAL, THE AMOUNT AND TYPE OF VEGETATION REFLECTS THE AMOUNT AND SEASONAL DISTRIBUTION OF RAINFALL, WHILE EROSION REFLECTS THE INTENSITY AND AMOUNT OF INDIVIDUAL RAINS, OR THE CLOSE COINCIDENCE OF SEVERAL RAINS IN TIME OR SPACE.

THE PLANT COVER OF AN AREA IS ESSENTIALLY DEPENDENT ON RAINFALL, ALTHOUGH THIS DEPENDENCY IS MODIFIED BY FACTORS OF TEMPERATURE, HUMIDITY, AND SOIL PROPERTIES. UNDER VIRGIN CONDITIONS THE AMOUNT AND TYPE OF PLANT COVER WOULD VARY WITH RAINFALL. SIMILARLY, EROSION CONDITIONS ARE DEPENDENT ON VEGETATIVE COVER AS WELL AS SOIL PROPERTIES AND RAINFALL.

GIVEN, THEN, A FLUCTUATING COVER OF VEGETATION ON AN AREA, WHAT EFFECT WOULD THESE FLUCTUATIONS HAVE ON RUN-OFF AND EROSION? MEASUREMENTS OF THE RATE AT WHICH SOILS WILL ABSORB WATER HAVE SHOWN A MARKED CORRELATION BETWEEN THE DENSITY AND VOLUME GROWTH OF VEGETATION, ON ONE HAND, AND THE INFILTRATION RATE OF WATER, ON THE OTHER. THE MORE VEGETATION THE MORE RAPIDLY THE SOIL ABSORBS WATER. BUT WHILE A GIVEN REDUCTION OF PLANT COVER MAY DECREASE THE RATE OF WATER INTAKE BY ONLY 10 TO 20 PER CENT, THAT REDUCTION MAY INCREASE THE AMOUNT OF SEDIMENT MOVED FROM EIGHT TO A HUNDRED TIMES. THUS, RAINS OCCURRING DURING PERIODS OF DROUGHT AND REDUCED PLANT COVER PRODUCE A SMALL INCREASE IN RUN-OFF WITH AN ENORMOUS INCREASE IN SOIL MOVED. THIS RESULTS IN ACTIVE CUTTING AT ONE POINT, BUT ACTIVE FILLING DOWNSTREAM AT ANOTHER.

IN THE SOUTHWEST, THERE IS A STRIKING DIFFERENCE IN THE SHORT-GRASS, RELATIVELY SPARSE HILLSIDE VEGETATION, AND THE LONG DENSE GRASSES OF THE ALLUVIAL VALLEY BOTTOMS. WATER FROM THE HILLSIDES AND SMALL TRIBUTARY DRAINAGES COLLECTS IN THE VALLEY BOTTOMS, GIVING THEM WATER BY FLOOD IRRIGATION IN ADDITION TO THAT RECEIVED DIRECTLY FROM PRECIPITATION. THE FLOOD WATER INCREASES THE GROWTH AND DENSITY OF THIS VEGETATION. IN TURN, THE GREAT DENSITY AND VOLUME OF THESE GRASSES PROTECT THE VALLEYS AGAINST MOST FLOOD FLOWS FOR, UNDER NORMAL CONDITIONS, RUN-OFF FROM TRIBUTARY AREAS IS LOST IN THE RELATIVELY WIDE, FLAT, GRASSY VALLEYS, THE SEDIMENT LOAD BEING DEPOSITED AS VELOCITY AND FLOW DIMINISH. IN HIGH FLOWS, THE FORCE OF THE MOVING WATER LAYS THE GRASS ON THE GROUND, CREATING A PROTECTIVE GRASS PAVEMENT IN THE WATERCOURSE. THUS VEGETATION PROTECTS ALLUVIAL VALLEYS FROM ALL BUT THE GREATEST STORMS.

EVEN IN DRY PERIODS THE VEGETATION OF THESE VALLEYS HAS A BETTER CHANCE OF SURVIVAL THAN THAT ON THE TRIBUTARY AREAS. WATER RECEIVED FROM FLOOD RUN-OFF IS USUALLY SUFFICIENT IN EVEN THE DRIEST YEARS TO PRODUCE PROTECTIVE VEGETATION.

IN ANY PERIOD, HOWEVER, THERE ARE INFREQUENT STORMS OF HIGH INTENSITY AGAINST WHICH EVEN A WELL-VEGETATED AREA IS NOT ADEQUATELY PROTECTED, AND RAPID RUN-OFF OCCURS. THIS INTENSE RUN-OFF CREATES HIGH FLOWS OF WATER WITH GREAT VELOCITY AND CUTTING POWER. EROSION OCCURS AT STORM LOCATIONS IN THE TRIBUTARY DRAINAGES, AND GULLIES FORM AT POINTS OF RUN-OFF CONCENTRATION OR WEAKNESS IN THE ALLUVIAL VALLEYS. BUT AS THE FLOOD TRAVELS DOWN THE VALLEY, MUCH OF ITS WATER IS TEMPORARILY STORED IN THE FILLING OF THE VALLEY BOTTOM, AND SOME IS LOST THROUGH ABSORPTION. AS THIS TAKES PLACE, THE INTENSITY OF FLOW AND VELOCITY IS REDUCED, VEGETATIVE PROTECTION BECOMES EFFECTIVE, THE FLOW CEASES TO CUT AND DROPS MOST OF ITS SEDIMENT LOAD. UNDER THESE CONDITIONS, EROSION IS LOCALIZED. WHILE THERE IS CUTTING AT THE POINTS OF GREATEST STORM AND FLOOD INTENSITY, THERE IS DEPOSITION AND BUILDING OF THE VALLEY FLOOR AT OTHER POINTS.

THUS, THE ORIGINAL ALLUVIAL VALLEY PRESUMABLY SHOULD HAVE HAD, AND EVIDENCE INDICATES THAT IT DID HAVE, A SERIES OF DISCONTINUOUS GULLIES, THEIR POSITION AND LENGTH DEPENDING ON THE CHANCE LOCATION OF HEAVY STORMS WITHIN ITS TRIBUTARY DRAINAGE.

MUCH HAS BEEN MADE, BY MANY PEOPLE, OF THE CHANGE OF CLIMATIC CONDITIONS. THE SUPPOSED CHANGE HAS BEEN SO OFTEN PUT FORWARD AS A CAUSE OF SOME OTHER CHANGE THAT IT MIGHT BE WELL TO EXAMINE AVAILABLE RECORDS TO SEE WHAT THEY INDICATE. RECORDS OF PRECIPITATION IN THE SOUTHWEST BEGIN AT SANTA FE, IN 1849, AND AT TUCSON, IN 1868. ANALYSIS OF THESE RECORDS INDICATES NO MORE VARIATION IN RAINFALL FROM YEAR TO YEAR THAN WOULD BE EXPECTED IN A RANDOM SERIES OF THAT LENGTH. THE STUDY OF TREE RINGS HAS ENABLED US, WITH SOME DEGREE OF SUCCESS, TO ESTABLISH SOME MEASURE OF RAINFALL AT EARLIER DATES. THOUGH THERE ARE DEFINITE INDICATIONS OF PERIODS OF SEVERE DROUGHT, THERE IS NO EVIDENCE THAT THEY ARE DUE TO A CHANGE OF CLIMATE OR THAT THEY ARE ANYTHING MORE THAN THE WIDE VARIATION FROM THE NORMAL OCCURRENCE WE SHOULD EXPECT OVER A LONG PERIOD OF TIME. WE FIND THAT THE QUESTION OF CLIMATIC CHANGE OVER THE PERIOD IN QUESTION COMES DOWN TO A DEFINITION OF TERMS. DIFFERENCES BETWEEN THE CLIMATE OF DIFFERENT PERIODS ARE ADMITTED, BUT IT ALSO SEEMS CLEAR THAT THESE DIFFERENCES ARE FORTUITOUS, HAVE NO DEFINITE PERIOD OF RECURRENCE, AND DO NOT SHOW ANY SUSTAINED TREND.

GRANTED THAT IN THE PAST THERE WERE PERIODS OF DROUGHT MORE SEVERE THAN ANY RECORDED IN RECENT TIMES, LET US EXAMINE DOCTOR BRYAN'S CONCLUSION THAT ARROYO CUTTING OCCURS IN DRY PERIODS.

ANALYSIS OF RAINFALL RECORDS INDICATES THAT INTENSE RAINFALLS ARE MUCH LESS LIKELY TO OCCUR IN DROUGHT PERIODS THAN IN HUMID PERIODS. FEW INTENSE STORMS WOULD BE EXPECTED IN A PROLONGED PERIOD OF DROUGHT. CONTINUED DROUGHT WOULD DECREASE PLANT COVER ON TRIBUTARY DRAINAGES. AS HAS ALREADY BEEN SHOWN, THIS WOULD INCREASE THE AMOUNT OF RUN-OFF FROM A GIVEN STORM ONLY SLIGHTLY BUT WOULD GREATLY INCREASE SEDIMENT MOVEMENT. BUT THE INCREASE IN RUN-OFF WOULD TEND TO REDUCE THE EFFECT OF DROUGHT IN THE ALLUVIAL VALLEYS, WHERE SOME FLOOD IRRIGATION WOULD MAINTAIN FAIRLY DENSE GRASS THAT WOULD BE PROTECTION AGAINST MINOR FLOODS. INTENSE STORMS WOULD BE MORE INFREQUENT THAN IN WETTER PERIODS. WHEN THEY OCCURRED, DISCONTINUOUS GULLIES WOULD BE FORMED. BUT THE INFREQUENCY OF HEAVY STORMS, TOGETHER WITH INCREASED SEDIMENT LOADS OUT OF ALL PROPORTION TO INCREASED RUN-OFF FROM SMALLER STORMS, SHOULD RESULT IN A BALANCE OF DEPOSITION. GULLIES WOULD NATURALLY FILL.

SO IT MUST BE CONCLUDED THAT A DROUGHTY PERIOD WOULD NOT BE A PERIOD OF VALLEY TRENCHING; THAT INFREQUENT HEAVY STORMS, RELATIVELY WELL-PROTECTED VALLEY BOTTOMS, AND HIGH SILT LOADS COUPLED TO RELATIVELY LOW WATER FLOWS WOULD RESULT IN A PERIOD OF AGGRADATION WITH ONLY DISCONTINUOUS CHANNELS SPOTTING THE ALLUVIAL VALLEYS.

SINCE CHANNEL FILLING APPEARS TO OCCUR IN A DRY PERIOD, IT MAY WELL BE ASKED WHAT THE EROSION SITUATION IS IN A WET PERIOD. RECORDS SHOW THAT DURING A WET CYCLE THE NUMBER OF INTENSE STORMS AND THEIR DISTRIBUTION OVER AN AREA INCREASE. BUT SINCE PLANT COVER ALSO INCREASES ON BOTH TRIBUTARIES AND IN ALLUVIAL VALLEYS WITH A GREATER WATER SUPPLY, THE VOLUME OF RUN-OFF INCREASES WITHOUT A CORRESPONDING INCREASE IN SEDIMENT LOAD.

THE MORE FREQUENT INTENSE STORMS, AS WE HAVE INDICATED, CUT AT SOME POINTS IN SPITE OF VEGETATIVE COVER, ERODE THESE POINTS RAPIDLY, AND CARRY EROSION PRODUCTS GREAT DISTANCES BECAUSE RUN-OFF AND FLOW ARE NOW GREATER IN PROPORTION TO THE MATERIALS TO BE CARRIED. THE ULTIMATE RESULT WOULD APPEAR TO BE MORE AND LARGER DISCONTINUOUS GULLIES, BUT THE GREAT RESISTANCE OF DENSE VALLEY-BOTTOM VEGETATION WOULD TEND TO PREVENT THE CUTTING OF CONTINUOUS CHANNELS.

IN CONCLUSION, THEN, IT CAN BE SAID THAT BOTH CUTTING AND FILLING CAN AND DO OCCUR IN EITHER WET OR DRY PERIODS. IN WET PERIODS, DISCONTINUOUS GULLIES ARE LARGER AND MORE NUMEROUS, WITH THE TREND TOWARD CUTTING; IN DRY PERIODS, THE TREND IS TOWARD FILLING BECAUSE FEWER AND SMALLER DISCONTINUOUS GULLIES ARE FORMED AND PREVIOUS GULLIES ARE MORE RAPIDLY FILLED.

THE DISCUSSION THUS FAR HAS DEALT WITH THE FORMATION OF DISCONTINUOUS CHANNELS. ANOTHER AREA OF DISAGREEMENT WITH DOCTOR BRYAN IS IN HIS ASSUMPTION THAT EROSION, AS EVIDENCED BY THE EXPOSURE OF ANCIENT CHANNELS, IS COMPARABLE TO THE EROSION ACTIVE TODAY. RECENT EROSION HAS DEVELOPED CONTINUOUS CHANNELS IN MANY ALLUVIAL VALLEYS. THESE VALLEYS HAVE BEEN CUT FROM ONE END TO THE OTHER WITH DEEP, VERTICAL-BANK ARROYOS. THIS IS TRUE IN MOST VALLEYS ON THE NAVAJO RESERVATION, THE RIO PUERCO, THE GALISTEO, THE SAN SIMON, THE SAN PEDRO, AND MANY OTHER DRAINAGES IN NEW MEXICO AND ARIZONA. WE HAVE NO EVIDENCE THAT THE EXPOSED REMNANTS OF OLD CHANNELS ARE MORE THAN SEGMENTS OF DISCONTINUOUS GULLIES. THERE IS NO EVIDENCE THAT THESE REMNANTS WERE PART OF CHANNELS EXTENDING THE FULL LENGTH OF THE OLD VALLEY FILL, AND THE ANALYSIS DEVELOPED IN THE PRECEDING PARAGRAPH WOULD INDICATE THAT THESE WERE DISCONTINUOUS GULLIES.

THE CUTTING OF A DEEP, NARROW CHANNEL THROUGH AN ALLUVIAL VALLEY HAS A GREAT EFFECT ON STREAM FLOW AND SEDIMENTATION. BOTH FLOW AND CARRYING POWER OF THE STREAM ARE INCREASED. THIS COMBINATION RESULTS IN RAPID ACCELERATION OF EROSION.

THE FORMATION OF A CHANNEL SHARPLY CONFINING WATER FLOW ALLOWS FLOOD WAVES TO MOVE A LONG WAY DOWN STREAM. FLOOD WAVES ARE GREATER BECAUSE CHANNELS GATHER WATER THAT WAS ONCE SPREAD OUT, CONCENTRATING IT IN ONE LARGE FLOW OF HIGH VELOCITY. SINCE IT IS LESS SPREAD OUT OVER THE DRAINAGE OR VALLEY FLOOR, THERE IS LESS TEMPORARY STORAGE OF WATER, LESS WATER ABSORBED BY THE SOIL, AND A FURTHER INCREASE IN THE FLOOD FLOW. WITH LESS ABSORPTION IN THE ALLUVIAL VALLEY FLOOR, GROUND WATER DECREASES AND VEGETATION ONCE FED BY FLOOD IRRIGATION DECLINES.

THE COMBINATION OF THESE EFFECTS LEADS TO THE FORMATION OF FLOOD FLOWS WITH GREATER CARRYING POWER THAT CUT THE NEW CHANNEL FURTHER INSTEAD OF DEPOSITING THE MATERIAL CARRIED. THE GULLY-LIKE CHARACTER OF THE CHANNEL, WITH LACK OF REDUCTION IN FLOWS AS THEY MOVE DOWNSTREAM, ALLOWS THE SOIL PICKED UP TO BE MOVED GREAT DISTANCES WITHOUT BEING DROPPED AND DEPOSITED.

THE EARLY STAGES IN EROSION CREATE FAIRLY STRAIGHT, VERTICAL-WALLED CHANNELS. OUR PRESENT ARROYOS ARE OF THIS TYPE. LATER STAGES OF THE PROCESS CREATE A MEANDERING STREAM THAT CUTS ITS BANKS UNTIL FINALLY A WIDER FLOOD PLAIN IS FORMED SOME DISTANCE BELOW THE ORIGINAL VALLEY FLOOR. AT THIS LAST STAGE, FLOWS ARE AGAIN SPREAD OUT, DEPOSITION OCCURS, AND VEGETATION IS ABLE TO TAKE HOLD ON THE NEWLY FORMED VALLEY. THE EVIDENCE OF THE FINAL STAGE OF EROSION IS A RELATIVELY WIDE AND SHALLOW CHANNEL SECTION.

SINCE MOST OF THE EXPOSURES OF THE BURIED CHANNELS DESCRIBED BY DOCTOR BRYAN DO NOT SHOW THIS SECTION, AND SINCE A CONTINUOUS GULLY COULD BE FILLED ONLY AFTER SUCH A SECTION HAD BEEN ATTAINED, IT SEEMS REASONABLE TO ASSUME THAT, IN MOST CASES AT LEAST, THE EXPOSED REMNANTS OF OLD CHANNELS CITED BY DOCTOR BRYAN REPRESENT PARTS OF DISCONTINUOUS CHANNELS AND NOT CONTINUOUS CHANNELS; AND THAT THESE CHANNELS ARE NOT COMPARABLE TO THOSE OF THE PRESENT DAY. THE MECHANICS OF FILLING A CONTINUOUS GULLY WITH THE CHARACTERISTICS OF THE OLD CHANNELS DESCRIBED BY DOCTOR BRYAN HAVE NEVER, TO THE AUTHOR'S KNOWLEDGE, BEEN ADEQUATELY DEVELOPED BY HIM.

THE MOST IMPORTANT AREA OF DISAGREEMENT WITH DOCTOR BRYAN IS IN HIS CONCEPT OF THE ROLE OF OVERGRAZING IN EROSION. THAT OVERGRAZING ACCELERATES EROSION BEYOND THE NORMAL RATE IS A FUNDAMENTAL ASSUMPTION OF THE UPSTREAM ENGINEER.

IT HAS BEEN SHOWN THAT FLOOD IRRIGATION OF THE ALLUVIAL VALLEYS PRODUCES DENSE STANDS OF GRASS ON THESE FLOORS, MORE THAN IS PRODUCED ELSEWHERE IN A SEMI-ARID REGION. WHEN WHITE MEN BROUGHT CATTLE AND SHEEP INTO THE SOUTHWEST, THEY OFTEN CONCENTRATED IN THE WELL-GRASSED AND RELATIVELY WELL-WATERED ALLUVIAL VALLEYS. USE WAS HEAVIEST THERE. THE RESULT WAS AN EARLY DESTRUCTION OF GRASS IN MANY OF THESE VALLEYS AND AN EARLY DECREASE IN THE PLANT COVER THAT HAD BEEN AN ESSENTIAL PROTECTION AGAINST CUTTING BY FLOOD FLOWS.

AS THE HIGH DENSE GRASS COVER DISAPPEARED, THERE WAS LESS OBSTRUCTION TO FLOW THROUGH THE VALLEYS, VELOCITIES INCREASED, AND CHANNELS WERE CUT IN THE VALLEY FLOOR. WATER WAS SPREAD OVER A SMALLER PART OF THE VALLEY UNTIL PLANT COVER DISAPPEARED THROUGH LACK OF IRRIGATION AS WELL AS THROUGH OVERUSE. THE WHOLE PROCESS OF VALLEY DESTRUCTION WAS CUMULATIVE SINCE STOCK CONTINUED TO CONCENTRATE ON REMAINING VEGETATION.

LACK OF PLANT COVER PLUS INCREASED VELOCITIES OF FLOWS ALLOWED EROSION TO BEGIN WHERE NONE HAD OCCURRED AS LONG AS RUN-OFF WAS SPREAD OVER THE VALLEY FLOOR. DISCONTINUOUS GULLIES INCREASED IN LENGTH AS VELOCITIES AND FLOOD FLOWS INCREASED.

ALL OF THESE AND RELATED CIRCUMSTANCES COMBINED TO INCREASE EROSION AND DECREASE DEPOSITION OF SEDIMENT. THE NET RESULT WAS A JOINING OF DISCONTINUOUS GULLIES TO FORM ONE LONG, DEEP-CUT CHANNEL THAT PUT AN END TO FLOOD IRRIGATION AND FORCED STOCK TO THE SIDE HILLS FOR MUCH OF ITS FORAGE.

HEAVIER GRAZING ON THE SIDE HILLS, BY THINNING PLANT COVER, ALLOWED AN INCREASE IN RUN-OFF AND A STILL HEAVIER INCREASE IN EROSION AND SILT PRODUCTION. IF THERE WERE NO CONTINUOUS GULLY IN THE VALLEY FLOOR, THE INCREASED SILT WOULD BE DEPOSITED. HOWEVER, THE CONCENTRATION OF ALL FLOWS IN THE NARROW DEEP CHANNEL PREVENTS THIS FROM TAKING PLACE IN THE VALLEYS. WE ARE IN THIS STAGE TODAY. THE SILT IS NOT DEPOSITED UNTIL FLOOD FLOWS STRIKE THE RELATIVELY FLAT BEDS OF THE MAJOR RIVERS. IT IS DUMPED THERE, WHERE IT IS EITHER LEFT TO FILL THE RIVER CHANNEL OR IS CARRIED BY RIVER FLOODS TO MAN-MADE RESERVOIRS.

THIS IS THE NEGATIVE ASPECT OF THE GRAZING PICTURE; FORTUNATELY, THERE IS EVIDENCE OF THE POSITIVE RESULT OF CONSERVATIVE USE. THERE ARE DRAINAGES AND ALLUVIAL VALLEYS THAT HAVE NOT BEEN OVERUSED, WHICH PRESENT A WELL-GRASSED, LARGELY UNGULLIED EXPANSE. THEY ARE NOT CUT FROM END TO END BY A RAW GULLY. THERE ARE OTHER AREAS, OVERUSED AND ERODING IN THE PAST, WHICH ARE HEALING WITH CONSERVATIVE USE.

THIS DISCUSSION HAS NOT INTRODUCED THE COMPLICATIONS RESULTING FROM THE CONCENTRATION OF WATER BY ROADS, TRAILS, HIGHWAYS AND RAILROAD CULVERTS, AND OTHER WORKS OF MAN, BUT IT SHOULD BE OBVIOUS THAT THESE CONCENTRATIONS WOULD INCREASE EROSION. SINCE THE USE OF A DRAINAGE AREA MEANS THAT THESE FACTORS WILL BE INTRODUCED, EFFECT OF MISUSE OF THE LAND BY GRAZING WILL BE AMPLIFIED. EVEN ON LAND CONSERVATIVELY USED, THE HARMFUL ACTION OF THESE FACTORS MAY BE SUCH AS TO INDUCE EROSION THAT CANNOT BE CHECKED BY NATURAL MEANS. THE SITUATION MAY BE FURTHER COMPLICATED BY UNWISE CULTIVATION OR WASTEFUL IRRIGATION PRACTICES.

IT IS RATHER INTERESTING TO NOTE THAT DOCTOR BRYAN HAS USED THE EVIDENCE OF HUMAN OCCUPATION FOUND IN ANCIENT BURIED CHANNELS TO STRENGTHEN HIS THEORY OF AN ARID PERIOD CAUSING EROSION, AND HAS USED THE KNOWLEDGE THAT THESE PEOPLE HAD NO CATTLE TO MINIMIZE THE INFLUENCE OF GRAZING ON THE FORMATION OF GULLIES.

WITH EQUAL FORCE, THE AVAILABLE EVIDENCE CAN BE USED TO SUPPORT A BELIEF THAT THE ANCIENT CHANNELS MAY HAVE BEEN CAUSED BY "ACCELERATED EROSION" DIRECTLY RELATED TO HUMAN OCCUPATION.

IT SEEMS TO BE THE GENERAL CONCLUSION THAT THESE ANCIENT PEOPLES PRACTICED SOME METHOD OF FLOOD IRRIGATION, DIVERTING WATER FROM EPHEMERAL STREAMS TO IRRIGATE THEIR CROPS. THE EFFECT OF THIS PRACTICE WOULD BE THAT ONLY THE INFREQUENT, HIGH DISCHARGES WOULD BE ALLOWED TO PASS DOWN THE VALLEY. THAT LOWER PORTION OF THE VALLEY, DEPRIVED OF ITS PLANT-SUSTAINING LOW FLOWS, WOULD BE SUBJECTED TO A MUCH GREATER EROSION HAZARD THAN WOULD HAVE BEEN THE CASE NATURALLY.

IT MAY BE ASSUMED THAT SUCH DIVERSION STRUCTURES AS WERE BUILT BY THESE ANCIENT PEOPLES WERE POORLY CONSTRUCTED. THE LOSS OF THESE STRUCTURES IN FLOODS, THE UNCONTROLLED MOVEMENT OF WATER DOWN DIVERSION DITCHES, AND OTHER FACTORS ALL WOULD TEND TO INCREASE THE EROSION HAZARD AT THE

POINT OF DIVERSION. IT WOULD SEEM TO BE MORE REMARKABLE IF EROSION DID NOT OCCUR WITH HUMAN OCCUPATION THAN THAT IT DID.

EROSION CONTROL OR UPSTREAM ENGINEERING IN THE SOUTHWEST ATTEMPTS TO USE, AT LEAST IN THE PLANNING STAGE, THE COMBINED TALENTS OF THE PLANT ECOLOGIST, THE HYDROLOGIST, AND THE ENGINEER, AS WELL AS MEN WHO HAVE SPECIAL TRAINING IN THE MANAGEMENT OF RANGE AND CROP LANDS. THE SOCIO-ECONOMIST HAS A SIGNIFICANT PART. THE JOB OF THESE MEN, WORKING WITH THE LAND USERS AND CHARGED WITH RESPONSIBILITY FOR INTEGRATING THEIR EFFORTS, IS TO EFFECT GOOD LAND MANAGEMENT, SUPPLEMENTED BY SUCH ENGINEERING MEASURES AS ARE CALCULATED TO PREVENT FUTURE DAMAGE. WHERE GULLY EROSION HAS REACHED AN ADVANCED STAGE, WHERE THE PEOPLE ON THE LAND ARE DEPRIVED OF RESOURCES THEY NEED FOR LIVELIHOOD, AND WHERE COMMUNITIES AND IRRIGATION PROJECTS DOWNSTREAM SUFFER FROM FLOODS AND SILT, SUBSTANTIAL SUMS OF MONEY AND THE MAXIMUM AVAILABLE AMOUNT OF HUMAN INGENUITY ARE REQUIRED.

SOMETIMES, AS IN THE CASE CITED BY DOCTOR BRYAN, HUMAN AND LAND RESOURCES ARE EQUALLY AT STAKE. THEN ALL THE TOOLS AVAILABLE TO PUBLIC AGENCIES MUST BE PUT TO USE. LAND PURCHASE, EROSION CONTROL, RURAL REHABILITATION FACILITIES, AND AID IN REPAIRING IRRIGATION WORKS ARE SOME OF THESE TOOLS. THE EFFECTIVENESS OF THE CONSERVATION EFFORT SHOULD NOT BE MEASURED SOLELY BY THE PRICE PER ACRE OF LAND OR THE COST OF ENGINEERING TREATMENT ON INDIVIDUAL TRACTS. EACH PART OF THE JOB SHOULD CONTRIBUTE TOWARD THE SOLUTION OF THE TOTAL PROBLEM. IF, AS THE WORK PROGRESSES, ITS VARIOUS COMPONENT PARTS CONTRIBUTE TOWARD THE DESIRED RESULT--RESTORING WATERSHED LANDS TO SOMETHING LIKE THEIR ORIGINAL STATE, REPOPULATING FARMS ABANDONED FOR LACK OF WATER, LESSENING FLOOD HAZARDS TO DISCOURAGED COMMUNITIES, AND LIFTING PEOPLE FROM A RELIEF STATUS TO SELF-SUPPORT--THE PROJECT MAY BE ADJUDGED WORTHWHILE.

BUT, FUNDAMENTALLY, CONSERVATION IS NOT A PROGRAM. IT IS A WAY OF USING THE LAND, A WAY OF SEEING AND VALUING THE LAND. IT IS ONLY BECAUSE THIS COUNTRY HAS APPROACHED LATE THE MORE INTELLIGENT USE OF ALL ITS FARM AND RANGE LANDS THAT THE TASK IS SO MAGNIFIED.

YOUR TRUE CONSERVATIONIST IS HUMAN AND, BEING HUMAN, MAKES MISTAKES. BUT HE KEEPS A GOAL IN VIEW, WEIGHS CRITICISM, AND PROFITS BY THAT WHICH IS MERITED. HIS WORK WILL STAND THE TEST IF HE BENEFITS THE MOST PEOPLE AND THE MAXIMUM AMOUNT OF LAND RESOURCES WITH THE MONEY AND TOOLS AT HIS COMMAND.